Intensive Care Med (1986) 12:328–331

Intensive Care Medicine

Portable lung ventilators: the potential risk from bacterial colonisation

M.P. Shelly*,[1], G.R. Park[1], R.E. Warren[2] and R.J. Whetstone[2]

Departments of [1] Anaesthetics and [2] Microbiology, Addenbrooke's Hospital, Cambridge, UK

Accepted: 31 October 1985

Abstract. Seven portable lung ventilators were investigated to assess the risk of bacterial colonization of the ventilator valve. One valve was deliberately contaminated with Serratia marcescens and the survival of organisms within the valve studied. Periods of colonization by Acinetobacter were found in all the hospital ventilators studied but none of those from the ambulance service. The potential risk to the patient from this organism is discussed and the importance of adequate storage and regular cleaning of the ventilator valve emphasised. Since humidification of the patients inspired gas during transfer is desirable, the use of a combined heat and moisture exchanger and microbiological filter would appear advisable.

Key words: Portable lung ventilators – Infection – Acinetobacter – Heat and moisture exchanger

Patients receiving artificial ventilation have the functions of their nose bypassed, so their inspired gases need to be warmed, humidified and filtered artificially. On an intensive care unit, the dry gases received by the patient are passed through a heated water humidifier or heat and moisture exchanger and, since ventilators have been implicated as a source of infection [8], measures are usually taken to reduce this risk. When patients are moved around or between hospitals, however, these factors may be neglected.

Several types of portable lung ventilator are now available for the transport of critically ill patients [1, 12] and while a heat and moisture exchanger may be used to provide humidification, the incidence of bacterial colonization of these ventilators is not known. During use, the patient valve of a portable lung ventilator is the only part of the ventilator which comes into contact with both the patient's inspired and expired gases, if bacterial colonization is a problem, therefore, this valve will be the point where it is most likely to be detected.

This study was undertaken to investigate whether or not bacterial colonization of the ventilator valve occurs and if so, to determine the natural history of this colonization.

Method

In the first part of the study, four portable lung ventilators, used for the transport of critically ill patients within the hospital, were studied; three pneuPAC ventilators (Pneupac Ltd.) and one Oxylog ventilator (Dragerwerk AG). The Cambridge Ambulance Station is on the hospital site and the pneuPAC ventilators from their three emergeny vehicles were subsequently included in the study, these being the most frequently used of their ventilators.

The ventilator valves were washed out by pouring 2 ml of sterile N/4 Ringers solution into the valve, agitating it for one minute and decanting the solution into a sterile container. Ringers solution was used so that nutrient would not be added to the system during the continuous use part of the study. A washout was performed after each use of the hospital ventilators and twice weekly in all the ventilators studied. No information is available on the reproducibility of bacterial recovery by this technique but it was used as a simple screening test.

0.1 ml aliquots of the elute were cultured on Cystine Lactose Electrolyte Depleted (LED) agar (Oxoid, CM301) and blood agar, incubated for 24 h and resulting colonies counted. Isolates were identified by standard microbiological tests and their antibiotic sensitivity patterns were determined by multipoint inoculation using single breakpoint inhibitory concentrations.

* Research Registrar in receipt of a grant from Napp Laboratories Ltd.

A further part of the investigation involved taking the pneuPAC ventilator from the Intensive Care Unit temporarily out of use and deliberately innoculating the valve with Serratia marcescens at a concentration of 1.4×10^7 colony forming units/ml. Washouts were performed at intervals to assess the effect, if any, of various manoeuvres on bacterial survival. The ventilator was stored for a week at a room temperature of 20 °C and for a further week at an ambient temperature of approximately 10 °C. At one point in the study, the valve was flushed with 100% oxygen, washouts being taken during the procedure. At the end of the study period, it was rinsed thoroughly with tap water, washed with dilute detergent (Fairy Liquid, Procter and Gamble Ltd.) and finally soaked for 18 h in 2% glutaraldehyde solution, washouts again being taken at intervals during this. Aliquots of the washout solution were diluted from 10^{-1} to 10^{-9} and cultured using a Miles and Mizra drop count technique [11] in triplicate on CLED medium. After incubation at 37 °C for 24 h, the colonies were counted and a mean of the three counts at the appropriate dilution determined.

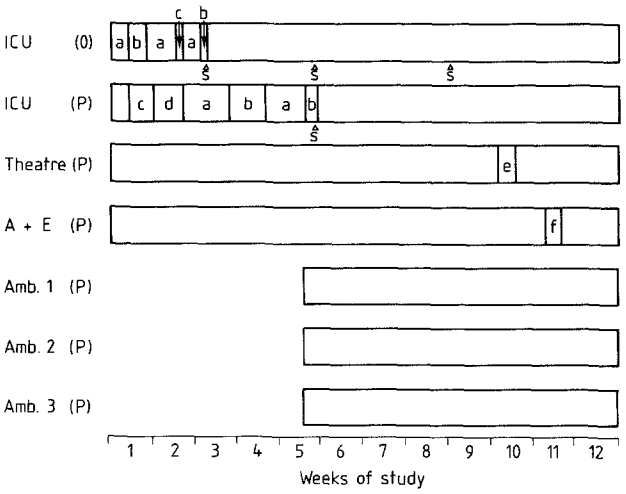

Fig. 1. Periods of colonization detected and the organisms identified in the various ventilator valves during the study period. Bacterial colonization was not found in any of the ambulance ventilator valves during this period. The organisms, a – f, were identified according to their antibiotic susceptibility. (O) = oxylog; (P) = pneuPAC; S = disinfected by immersion in glutaraldehyde; ICU = intensive care unit; A + E = accident and emergency; Amb = ambulance service ventilators

Results

The location of the ventilators studied and the number of times they were used during the 12-week study period are shown in Table 1. The mean duration of use of the hospital ventilators was 25 minutes (range 10 – 120 min). It was impossible to estimate the mean duration of use of the ambulance ventilators since records of use are not kept, however, none were used for long transfers.

Figure 1 shows the periods during which colonization was detected in the various ventilators together with the bacterial strain isolated, as determined by antibiotic sensitivity patterns. The Oxylog ventilator was colonized from the start of the study and remained so until it was disinfected with 2% glutaraldehyde solution. The pneuPAC ventilator from the Intensive Care Unit became colonized shortly after the study had commenced and it too remained colonized until disinfected. No bacterial growth was cultured from the remaining hospital pneuPAC ventilators for the majority of the study period; however, low colony counts were obtained from both ventilators which cleared without intervention. All three hospital pneuPAC ventilators became colonized spontaneously, they had not been used immediately prior to detection of organisms. During the entire study period, none of the pneuPAC ventilators used by the ambulance service was shown to be colonized. Several of the early washouts from the hospital pneuPAC ventilators also contained significant amounts of particulate debris.

Table 1. The location of the portable lung ventilators studied and the number of times each was used during the 12-week study period

Location	Ventilator type	Use during study period
Intensive care unit	pneuPAC	1
	Oxylog	36
Operating theatre	pneuPAC	1
Accident and emergency	pneuPAC	5
Ambulance station	pneuPAC	10
	pneuPAC	10
	pneuPAC	10

The organisms cultured were identified as Acinetobacter calcoaceticus var. anitratus. These organisms are resistant to a large number of commonly used antibiotic drugs, notably the aminoglycosides. The antibiotic sensitivity pattern of the most frequently cultured organism, organism a, is shown in Table 2. Six distinguishable antibiotic susceptibility patterns were found and the frequency with which each was detected is shown in Figure 1. Both the operating theatre and accident and emergency department ventilators were colonized by unique organisms, while the same organisms were found at different times in the two Intensive Care Unit ventilators. The different patterns may indicate a mixed growth of bacteria with sampling variation, or changes in the colonizing strain.

The results obtained from washouts of the ventilator valve deliberately contaminated with Serratia mar-

Table 2. The antibiotic sensitivity pattern of the strain of Acinetobacter most commonly isolated from the ventilator valves during the study period (strain a in Fig. 1)

Resistant	Sensitive
Colistin – 6	Cotrimoxazole – 4/20
Cephradine – 8	Ceftazidime – 8
Cephotaxime – 8	Piperacillin – 32
Cefoxitin – 8	
Ampicillin – 8	
Augmentin – 8/4	
Trimethoprim – 2	
Gentamicin – 4	
Tobramycin – 4	
Amikacin – 8	

cescens are shown in Figure 2. At point a, two 10-ml washouts were performed which reduced the bacterial colony count slightly. The ventilator was then left at ambient temperature for 18 h and a further fall in the number of bacteria was noted. Subsequent storage was at room temperature and at point b, the count had risen to a level greater than that of the original inoculum. This level of colonization was maintained over the following week, declining only slightly. At point c, the valve was flushed with oxygen; the number of colonies counted rose as soon as ventilation started, not until 20 breaths had been delivered, point d, did the colony count diminish. Storage following this was at ambient temperature and the bacterial colony count rose gradually over the week. At point e, the ventilator valve was rinsed with tap water and the colony count fell; washing with dilute detergent, at point f, had little additional effect. Not until the valve was soaked in glutaraldehyde solution did the ventilator valve finally become sterile.

Discussion

Since bacterial colonization of the valves of hospital portable lung ventilators was detected, a potential risk

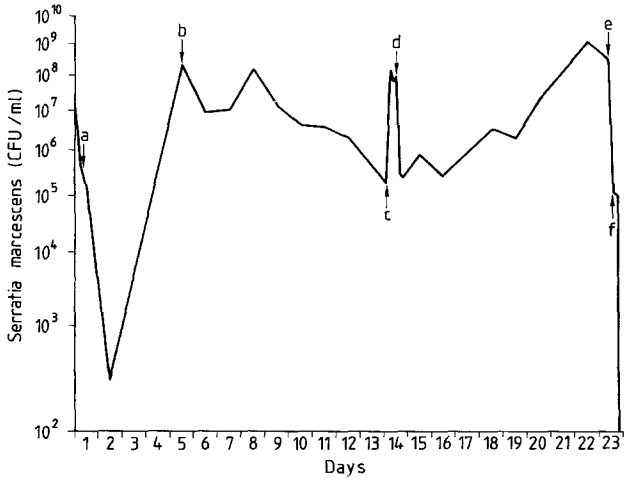

Fig. 2. The natural history of colonization of the ventilator valve innoculated with Serratia marcescens. See text for definition of labelled points. cfu = colony-forming units

to the patient exists. The results from the ventilator valve innoculated with Serratia marcescens indicate that organisms are capable of survival within the valve and may only be removed by terminal disinfection. The differences in colony count under the various conditions investigated are probably insignificant and accounted for by the error intrinsic in the technique used.

All bacteria cultured from the ventilator valve were Acinetobacter calcoaceticus, normal skin commensals generally regarded as low-level pathogens. Other, more pathogenic, gram negative organisms may, however, also be able to colonize the valve. No patient on whom the equipment was used during the study period had an Acinetobacter infection and no organism isolated from the patients was found in the ventilator valves. In the two months prior to the study, however, Acinetobacter colonization was detected in two patients, both of whom were transferred using the Oxylog ventilator. In one of these patients an Acinetobacter strain, which had an antibiotic sensitivity pattern similar to a strain subsequently cultured from the Oxylog ventilator during the study period, was isolated from a tracheostomy tube tip and the tracheostomy site.

Acinetobacter have been implicated in a wide variety of infections, or at least colonizations, commonly respiratory infections [6, 7, 14]. Respiratory equipment has also been identified as a source of infection [5]. Patients residing in intensive care units, those receiving antibiotic therapy, those with a compromised immune system or those in whom the natural defence mechanisms have been breached by cannulae, catheters or tubes are most liable to such infections [7, 14] and most likely to require artifical ventilation and transport within or between hospitals. Treatment of Acinetobacter infections may be difficult because of the multiple antibiotic resistance seen in this organism. It is also possible that Acinetobacter act as a reservoir or vehicle of transmissable drug resistance [15] as well as being occasionally pathogenic.

None of the ambulance service ventilators was colonized during the study period. This may be due in part to the different populations ventilated by the ambulance and hospital teams. Exposure to the range of hospital organisms is avoided by the ambulance ventilators but not by those in hospitals.

Another, more important factor, is the different standard of care given to equipment by ambulance and hospital staff. The first priority of hospital staff receiving a transferred patient is to treat that patient and time for maintaining equipment is limited. Portable lung ventilators may, therefore, be cleaned irregularly, checked rarely and stored inadequately. The ambulance crew, on the other hand, make time for their equipment after delivering a patient, since alternatives may not be immediately available. Their port-

able lung ventilators are cleaned after every use, checked regularly and stored neatly. After each use the ventilator valve is washed thoroughly with soapy water and disinfected with 0.015% chlorhexidine solution, although the latter will probably have little beneficial effect.

Regular cleaning and adequate storage are clearly important. The valve of the Oxylog is easily detachable and can be autoclaved or disinfected. Additional valves may be obtained so that cleaning after each use is a practical possibility without removing the entire ventilator from service. However, the valve must be checked before use since incorrect reassembly is possible. The pneuPAC valve is less easy to remove from its high pressure oxygen pipeline and autoclaving is not possible; incorrect reassembly is unlikely and the valve is robust.

Protection of the valve may be achieved by using a heat and moisture exchanging filter at the catheter mount. This would filter the patients inspired gases, protect the ventilator valve from any patient organisms and act as a heat and moisture exchanger. Although the indiscriminate use of bacterial filters on breathing circuits in anaesthesia may not be justified [13], their place in the intensive care unit would seem to be established. The risk of acquired infection from ventilator circuits [8] is increased by the often prolonged duration of ventilation in critically ill patients. The use of breathing circuit filters on the inspiratory and expiratory limbs of the ventilator circuit, help to minimize this risk by isolating the patient from the ventilator. Inadequate humidification of the patient's inspired gases has important consequences. Heat loss leads to a drop in body temperature with its attendant metabolic problems [10] and loss of water from the respiratory tract causes the bronchial endothelium to lose its cellular integrity with loss of cilial function and consequent sputum retention [3]. These changes occur rapidly and are reversible with adequate humidification; no benefit is obtained when a saturated vapour is provided [3, 10]. Several heat and moisture exchangers have claimed antibacterial properties but these claims have been challenged [2, 9]. Recently an established and effective bacterial filter (MP Shelly, unpublished observations), the Pall Ultipor BB50, has been demonstrated to be an efficient heat and moisture exchanger [4] and its use when transporting patients around or between hospitals would appear advisable. The use of such a filter by the emergency services, however, would not seem to be justified on the basis of this study.

Conclusion

Bacterial colonization of the valve of portable lung ventilators in a hospital has been demonstrated and this must pose a potential risk to the critically ill patient. Regular cleaning and proper storage would appear important in maintaining the sterility of the valve and the use of a heat and moisture exchanging bacterial filter, such as the Pall Ultipor Filters, may help to minimize the risk.

Acknowledgements. We would like to thank the staff of the microbiology laboratory, particularly Dr. S. Broughton for her technical help, also the Cambridge Ambulance Service, Mr. H. Sherriff, Director of the Accident Service, Mr. I. Bates, Senior Nursing Officer, Operating Theatre Suite and the medical and nursing staff of the Intensive Care Unit for their help and encouragement with this study.

References

1. Adams AP, Henville JD (1977) A new generation of anaesthetic ventilators. Anaesthesia 32:34
2. Bygdeman S, von Euler C, Nystrom B (1984) Moisture exchangers do not prevent patient contamination of ventilators. A microbiological study. Acta Anaesthesiol Scand 28:591
3. Chanlon J, Loew DAY, Malebranche J (1972) Effects of dry anaesthetic gases on tracheobronchial ciliated epithelium. Anesthesiology 37:338
4. Chanlon J, Markham JP, Ali MM, Ramanathan S, Turndorf H (1984) The Pall Ultipor Breathing Circuit Filter – An efficient heat and moisture exchanger. Anesth Analg 63:566
5. Cunha BA, Gracewski J, Klimek JJ, McLaughlin JC, Quintiliani R (1980) A common source outbreak of Acinetobacter pulmonary infections traced to Wright respirometers. Postgrad Med J 56:169
6. Gerner-Smidt P, Hansen L, Kundsen A, Siboni K, Sogaard I (1985) Epidemic spread of Acinetobacter calcoaceticus in a neurological department analyzed by electronic data processing. J Hosp Infect 6:166
7. Glew RH, Moellering RC, Kunz LJ (1977) Infections with Acinetobacter calcoaceticus (Herellea vaginicola): clinical and laboratory studies. Medicine 56, 2:79
8. Im SWK, Fung JPH, Yu DYC (1982) Unusual dissemination of pseudomonads by ventilators. Anesthesiology 37:1074
9. Leigh JM, White MG (1984) A new condenser humidifier. Anaesthesia 39:497
10. Linko K, Honkavaara P, Nieminen M-T (1984) Heated humidification in major abdominal surgery. Eur J Anaesthesiol 1:285
11. Miles AA, Misra SS (1938) The estimation of the bacteriocidal power of the blood. J Hyg Camb 38:732
12. Park GR, Johnson S (1982) A ventilator for use during mobile intensive care and total intravenous anaesthesia. The Drager Oxylog. Anaesthesia 37:1204
13. Ping FC, Oulton JL, Smith JA (1979) Bacterial filters – are they necessary on anaesthesia machines? Canad Anaesth Soc J 26:415
14. Ramphal R, Kluge RM (1979) Acinetobacter caloaceticus variety anitratus: an increasing nosocomial problem. Am J Med Sci 277, 1:57
15. Vivian A, Hinchliffe E, Fewson CA (1981) Acinetobacter calcoaceticus: some approaches to a problem. J Hosp Infect 2:199

Dr. M. P. Shelly
Department of Anaesthesia
Addenbrooke's Hospital
Hills Road
Cambridge CB2 2QQ
UK